

CONTRIBUTIONS TO THE BIOLOGY AND ETHOLOGY OF THE RED-EARED FIRETAIL (*ZONAEGINTHUS OCULATUS*)

By KLAUS IMMELMANN, c/o C.S.I.R.O. Wildlife Survey Section,
Nedlands.

INTRODUCTION

This study is based on field observations on a single population of the Red-eared Firetail (*Zonacginthus oculatus*) in the Wongong Gorge in the Darling Range, near Armadale, Western Australia. It is concerned with the behaviour of the species compared with other Australian finches I have investigated, especially the Beautiful Firetail (*Z. bellus*) which I have studied in Tasmania. Hitherto both the behaviour and the nature of the calls of *Zonacginthus oculatus* were relatively unknown (Morris, 1958). My Wongong studies were made during the 1959-60 season.

HABITAT

Four pairs of Red-eared Firetails were constantly present in the study area. This was a broad gorge heavily covered with a dense undergrowth and lightly forested with Marri (*Eucalyptus calophylla*). Through the valley ran a small creek known to hold water throughout the year. The locality is only 22 miles from the city of Perth.

The Beautiful Firetail has been found in similar habitats in Tasmania, but it does not seem to be as specialised as the Red-eared Firetail. It lives in a wider variety of habitats, from lightly forested country to open swamps. Furthermore, it even ventures into the gardens of towns and has been observed in Hobart several times. It is much less shy than its South-Western Australian relative.

Contrary to other Australian finches, tenacity to the one environment and solitary habits appear characteristic of the Red-eared Firetail and the unmated individuals and pairs alike demonstrated this strikingly during my observations at Wongong. In both the breeding and non-breeding seasons I found the birds regularly within their fairly large territories, which under normal conditions they never seemed to leave. This same persistence in one area has also been noted in the Beautiful Firetail (Ashby, 1920). The Western Australian species, however, appears to be even more extreme in its addiction to solitary existence. At Wongong no more than two adults or three young birds were ever seen together. This applied also to the non-breeding season. At this period the Beautiful Firetail forms flocks of up to 12 individuals (Gould, 1865; Cayley, 1932).

LOCOMOTION

The flight of both the Red-eared and Beautiful Firetails is light, steady and relatively slow, with scarcely any undulations. This is in considerable contrast to the flight of other Australian finches living in a more open environment. Their flight is rapid and vibra-

tile, with distinct undulations. As a rule the Red-eared Firetail flies low. I have often seen it from one to two feet above the ground, weaving with great dexterity around trees and shrubs. Higher flight, however, is resorted to when longer distances are to be traversed, and is necessary in reaching the nest, which is usually high in a tree.

Whilst the birds are on the wing there is no song or calling. Air-borne calling, as heard in many other Australian finches, is quite unnecessary in this species since it characteristically does not form flocks. The Beautiful Firetail and the Diamond Firetail (*Z. guttatus*) also possess a flight call. In the flocking finches this type of call serves to hold the group together.



Fig. 1.—Locomotion in the Red-eared Firetail; left row, pivoting up a vertical branch; middle row, pivoting down a vertical branch; right row, method of descending branches of a tree.

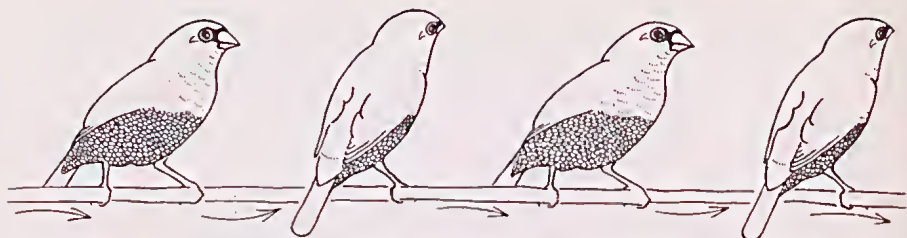


Fig. 2.—Red-eared Firetail pivoting along a horizontal branch.

When flying in sunlight the vivid red rump of all the species of *Zonaeginthus* is displayed with the clarity of a motor car's tail lights. This feature fades to relative obscurity in shade.

As in all Australian finches movement over the ground is performed by hopping, both feet in unison. Actually the Red-eared Firetail is very seldom seen on the ground itself, for even when feeding it prefers to sit on fallen twigs or branches. This is in striking contrast to the Beautiful Firetail in south-east Australia which is to be seen freely hopping and feeding on the ground and which does not share the western bird's marked adaptation to life amongst twigs and branches of trees. The Red-eared Firetail, in fact, is unsurpassed among the Australian finches in its ability to manoeuvre in and around the foliage of trees and bushes.

Ascending perfectly vertical twigs it releases its foothold to pivot to one side with each upward thrust. As the succeeding hop is made the pivot brings the bird over to the alternate side (Fig. 1, left row). Movement along a horizontal branch is also performed in arcs from side to side with pivoting hops (Fig. 2).

In descending limbs of a tree, one of two methods are employed. The bird usually leans out from a horizontal bough in the direction of a lower one, and, maintaining its foothold, falls forward as though beginning to rotate around its perch. When suspended upside down, it will suddenly relax its grasp and drop. Thus it comes down from branch to branch (Fig. 1, right row).

Rarely the side to side pivoting hop may be resorted to in the descent of a twig. In this situation the bird's body is hanging almost vertically, head directed downward, with the legs horizontal as the feet clutch the twig. Continually in this position, the pivots are executed in exactly the same manner as has been previously described. Foothold is momentarily lost as the bird hops (Fig. 1, middle row). So adept in these features, the Red-eared Firetail is able to hop straight through undergrowth that would force other finches to remain at the periphery. Being quite dense these bushes would present an impenetrable barrier to other species of finch, and would undoubtedly compel the bird to fly around to reach the opposite side.

With one exception, the wings and tail of the Red-eared Firetail are not obviously moved in the manner characteristic of other finches. When not in flight the wings are held absolutely motion-

less. There is no sign of the typical finch-like flicking. Further, it is only when the bird turns to one side that any appreciable diversion from the normal is obvious in tail movement. The tail is taken a little further through the air made by the body of the turning bird, so that it is twisted out of its natural position.

I believe that this exaggeration of the tail turn is the origin of the more highly evolved tail motions seen in other finch species. The tail movements are the same in the Beautiful Firetail.

FOOD AND FEEDING HABITS

As stated by Serventy and Whittell (1951), grass seeds form the main diet of the Red-eared Firetail. I usually found the birds to be feeding on *Lepidosperma angustatum*, while Sutton (1926) identified seeds from the stomach contents of the Beautiful Firetail as belonging to a species of *Stipa*. Seeds of trees and shrubs are also taken. A further record of the diet of the Red-eared Firetail comes from H. E. Tarr (1948) who observed them eating the "nuts" of *Casuarina*. During the breeding season, both the Western Australian and south-east Australian Firetails pick small insects from the foliage (Cayley, 1932, 1958).

Seldom seen on the ground itself, the Red-eared Firetail usually feeds whilst perched on a fallen twig, beneath a tree or bush. Securing a hold on the seed head of a piece of grass, the bird will pull it forward with the bill, until it is able to clutch at the stem immediately behind the seed head with one foot. The seeds are then removed. When the supply in one particular head is exhausted, the foot grasp is relaxed and the empty grass allowed to spring back. Then, pivoting from side to side on its perch, the bird will detect another seed head and repeat the procedure.

When actually feeding on the ground a Red-eared Firetail persistently hops back to twigs scattered nearby, and pauses thereon to look about the area before resuming its meal. It will thus interrupt its own feeding approximately every minute. As in feeding from a fallen twig one foot is used to hold the grass. Sometimes it will alight at the foot of a plant just beneath the seed head, and pick out the grain from there. There seems to be no preference for which foot is used in holding the grass. Both are employed impartially. In keeping with its weaker adaptation to twig life the Beautiful Firetail mostly feeds on seed heads of grasses lying on the ground and very seldom uses its feet to hold a piece of grass.

If feeding from the side of a bush no attempt is made to grasp the inflexible branches in the same manner as is the grass. Instead the bird will alight as close to the seeds as possible, reach out if necessary, and take them direct.

As a consequence of its general solitary habits this finch feeds alone, and in shrubbery, not out in the open as do the other Australian grass-finches. As stated previously, the absence of a contact call correlates with the absence of flocking.

CALLS

I have found that the Red-eared Firetail utters three types of call. The first, already known, is a nearly monosyllabic *Identity Call*. The other two, previously unrecorded, I have named the *Intimate Nest Call* and the *Nest Site Call*.

The Identity Call can best be expressed verbally by the sound "oowee," but the note as heard from the bird seems to have neither beginning nor end. It is very difficult to locate the calling bird by its sound. It floats in the air and trails off in all directions, so that the sound could have originated anywhere one looks.

It is quite audible, and is uttered whilst the bird is sitting on a branch. During the vocalisation there is no movement of wings or tail, such as is characteristic of other finches in similar circumstances. The bill is kept completely closed, or barely half a millimetre open. Throat movements, however, are quite obvious. With every call the neck is stretched slightly as the head and bill are tilted in a faintly downward direction. The same remarks apply to the Beautiful Firetail, in which species the Identity Call is even more monosyllabic and might be rendered as "weee."

The Identity Call may be given as a single note, or part of a series of the same notes. In the non-breeding season the single note is the most common. It is also uttered during bathing, preening or normal activity. Of spontaneous origin it appears to be involuntary and un-orientated. The same meaning may therefore be attributed to this call as for the social calls of other species of finches (Morris, 1958; Immelmann, 1959).

When uttered in a series it is repeated from two to 20 times. It becomes functional when thus used, and has a distinctly "searching" characteristic, enabling a pair of mated birds to hold contact with each other over considerable distances. The rhythm of the series is variable. Sometimes the interval between the notes is only as short as the note itself, but at other times it may be two or three times as long. Usually the bird calling a series receives an answer from its partner which may be several hundred yards further away in another part of the territory. The answering call consists of the same series of notes as those given. Sometimes, however, an answer is lacking.

Whilst one individual is vocalising the series call the other is silent, and only on the cessation of sound from its mate will it answer. The pair may thus reciprocate for several minutes, giving series of calls each consisting of about 20 notes followed by a few seconds' pause. It is not always that the bird answering the primary instigator of the call series comes to its mate. As a rule the activity engaged in before the calls were made is reverted to at the termination of a calling period.

For approximately half an hour the pair carry on normally, before the calls are again repeated in the same manner as already described. In this way contact is held between the mated pair separated within the territory by some distance.

I believe it also has a slight sexual significance (Immelmann, 1959), since it is heard most commonly in the breeding season, and is rare in the non-breeding season. It may serve for the synchronisation of the two birds constituting a pair, or in the definition of territorial rights. Coupled with the purpose of long distance contact-holding, these features bring this series calling of the Red-eared Firetail into the same class as the loud calling of other species of finch.

With a pair actively nesting, the series calls were even passed between the bird incubating on the nest and its mate foraging nearby on the ground. Since there is no distinctive sexual dimorphism in the Red-eared Firetail, I could not ascertain whether it was the male or the female bird which initiated vocalisation in this manner. Mated birds, like young of a common clutch, answer to each other. On the cessation of calling by one individual the other would sometimes continue for several minutes.

In some instances these calls are given when a bird is searching for a nesting site. However, it is not always associated with the carriage of a piece of grass in the bill in this case. Its purpose nevertheless, becomes identical with that of the actual Nest Site Call (see below).

If in fear, or disturbed, single birds will give the series call. It is probably a type of warning when thus used.

Generally the Red-eared Firetail is very quiet during the non-breeding season. When breeding, however, the birds become so vociferous that the gorge constituting the study area echoed to their calls. This is in direct contrast to the behaviour of other species of finches which are especially noisy during the non-breeding season.

The Intimate Nest Call is uttered when a previously foraging bird comes to the entrance of the nest where its mate is incubating eggs or covering young chicks. This greeting is di-syllabic in structure, which I have interpreted in the phrasing "twit twit."

Although the bill is held closed during the call the wings are quivered slightly with each note. It is a sharply-defined sound by which the bird can be directly located if the direction of the call is followed. The answering call given by the bird within the nest is composed of four syllables. The first note is long and pronounced, while the following three are slightly different from the first and given in a short staccato manner. The entire call may be rendered "tweet tit tit tit."

Immediately the incubating bird answers the "twit twit" of the mate outside, the latter will enter the nest where several further of the same call sequences are given. A few seconds later the bird relieved of its incubating duty appears at the nest entrance and flies off.

As far as is known no other species of finch possesses a call so intimate in nature. Coincidentally, no other finch builds a nest with the same structure as that of the Red-eared Firetail. The long,

relatively narrow tunnel obscures all sight of what lies within, so this call is presumably for protection. Through the mechanism of the Intimate Nest Call, the relieving bird may ascertain that the internal conditions of the nest are normal.

Confirmation of this theory was gained when an incubating bird was flushed from the nest due to my presence nearby. The relieving mate, arriving a short while later, called in the above described manner but naturally received no answer. After repeating the call for several minutes it hopped to the roof of the nest and waited. It was not until ten full minutes had elapsed that it began to move toward the entrance, which it doubtfully and hesitantly entered.

In normal circumstances the relieving mate enters the nest immediately the answer to its call is heard from within. If the flushed bird returns quickly it does not call prior to re-entering as it is aware of the nest being unoccupied.

The third call I describe as the Nest Site Call. The Red-eared Firetail utters these notes when in search of a suitable nesting place. There are six syllables in each phrase, the first of which is a variation of the Identity Call. Five short notes follow in rapid succession. Occasionally the first note is omitted. The entire phrase may be expressed as "oooweeeee üüüüü." The five short sounds are similar in character to the German umlaut "ü." The introductory "oooweeeee" is of somewhat shorter duration than the Identity Call, but is not as plain. The five short notes are uttered with continually fading intensity.

BREEDING

(i) THE SEARCH FOR A NESTING SITE

As is usual with finches the male Red-eared Firetail chooses the site on which the nest may be built, after which it is shown to the female for acceptance or rejection. In these cases, sex was surmised by behaviour.

In a suitable tree the male hops back and forth, searching, with or without a piece of grass held in his bill. Sometimes he will stop in front of a conspicuous place and give a series of Identity Calls. In this instance the male Red-eared Firetail exhibits a vestige of display remarkably similar in character to that of the Diamond Firetail (*Zonaeginthus guttatus*). The plumage of the underparts is fluffed out during the calling and a more erect stance adopted (Fig. 3). There is neither feather fluffing nor bodily erection during true Identity Calls, where the position is almost horizontal. The purpose in this display and utterance is very probably to attract the female so that she can be shown the site.

The call is, necessarily, given with closed bill, should the bird be holding a piece of grass. The grass itself is held in a unique manner (Fig. 3). It hangs vertically from the extreme tip of the bird's bill, its main length below and a small part projecting above the plane of the culmen. It thus appears to be impaled on the point of the mandibles, but I believe that it is very probably held in posi-

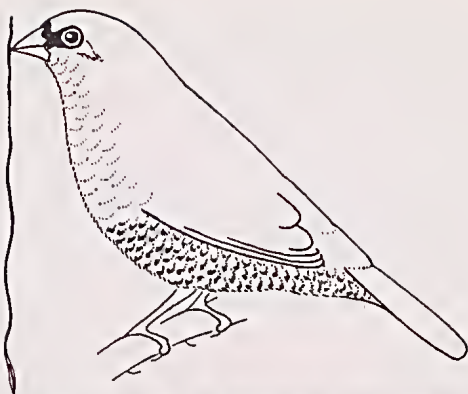


Fig. 3. —Red-eared Firetail holding grass and displaying.

tion by a peeled back strand of the stalk (Fig. 4). Green pieces of grass from 8 to 18 inches long are most frequently used, and only seldom are the dried yellow ones taken.

During flight and movement amongst branches the grass swings freely. Should it catch on a twig, the bird endeavours to release it by jerking his head back over to one side. In strong wind the grass is sometimes dropped as the call is made. It appears that vocalising and holding grass in the bill simultaneously are extremely difficult for this finch in more adverse weather conditions.

Symbolising nest building and breeding, the meaning in the carriage of a piece of grass by the male Red-eared Firetail is the same as that in the courtship of many species of finches (Steiner, 1955; Morris, 1958; Immelmann, 1959).



Fig. 4.—Mechanism of grass holding.

Depending upon the intensity of the nest building urge, the male may continue to search and call for as long as 45 minutes. If the female does not appear within this time the grass will be dropped and the bird flies off. Should the intensity be high, however, he obtains another piece of grass and begins over again. As soon as the female appears in the tree, the male hops to the denser foliage, where there may be a possible nesting site, and here gives the Nest Site Call as previously described. If he is still carrying the piece of grass, he will drop it now, prior to vocalising.

Contrary to the action of the Zebra Finch (*Taeniopygia castanotis*), the Red-eared Firetail never fans out the tail during a Nest Site Call.

The female Red-eared Firetail shows her acceptance of the site thus chosen by the male by flying to or alighting near him, and hopping about on the chosen branch, in a fork of which the nest will ultimately be built. Rejection of the site is displayed by the female's flying away from the area. When this happens the male will repeat the entire procedure in another tree some time later.

(ii) COURTSHIP

During the period of nest site searching and nest building the courtship activity is performed. The courtship behaviour of the Red-eared Firetail conforms to a large degree with that of other species of grass-finches (*loc. cit.*).

Courting is begun by the male bird as he utters the Nest Site Call with a piece of grass held at the tip of the bill. As soon as the female alights close by he will begin to jump back and forth between two branches, the piece of grass swinging pendulum-like with his momentum.

Directly upon landing after the completion of each jump he utters the call described above, although while in transit there is no vocalising. Still holding the piece of grass, he will eventually land near the watching female. Standing erect with the bill directed upwards he then commences to spring repeatedly up and down over the same spot, like a bouncing ball. The plumage will generally be fluffed out, but this feature is most noticeable in the abdominal region. The red ear-patches are not significantly erected.

At this stage a receptive female will begin to quiver her tail. As she does so the male drops the piece of grass and copulation follows.

Since the pair are usually high up in the tree, I cannot be certain as to whether there is any call during the bouncing dance.

(iii) NEST BUILDING

As is usual in Australian finches the male transports pieces of grass whilst the female sits in the growing nest and works them in. Green plant material is used exclusively. The grass is bitten off at ground level and by this end is carried to the nest. At the peak of nest construction activity one piece of grass is brought to the nest every 30 seconds (Peter Slater, personal communication). The material is gathered from the area beneath the nesting tree and is taken up in vertical flight, which resembles that of a beetle.

Having completed the outer parts of the nest the bird next gathers feathers and plant down which will be used as lining. A bundle of these articles is gathered together and held firmly in the middle as it is transported to the nest.

(iv) NESTING SITE

The Red-eared Firetail builds its nest higher above the ground than any other Australian finch. I found five nests from 25 to 50 feet up in the trees. As noted by Serventy and Whittell (1951), however, the Firetail in coastal areas may build in shrubs, such as *Hakea*. Campbell (1900) also found the nests in *Melaleuca* and *Banksia*.

In the Beautiful Firetail I found four nests from 6 to 22 feet from the ground. There were much higher trees in the neighbourhood and I conclude that this species does not favour as high an altitude for its nest as does the Red-eared Firetail. These four nests were built in introduced bushes (*Crataegus* spp.).

In my own study area at Wongong, the most frequently used sites were high in the forks of the outermost and denser branches of *Eucalyptus calophylla*.

The nest was usually set over a branch one-half to one inch in width, and was supported by surrounding twigs. In one case a nest had been placed in a dense mistletoe which had overgrown a large eucalypt. It was consequently very well camouflaged. Yet another was built on a branch overhanging the creek. A nesting site of this nature is characteristic of many species of Australian finches (Macgillivray, 1934; Campbell, 1900; Cayley, 1932).

In several instances a male Red-eared Firetail was observed with a piece of grass in his bill, uttering the Nest Site Call beneath the nest of a Brown Hawk (*Falco berigora*). This suggests that the Red-eared Firetail, in common with many other finches, also prefers to nest in the neighbourhood of birds of prey (cf. Souter, 1927; Sutton, 1927).

(v) THE NEST

When compared with the nests of other finches, it will be seen that the Red-eared Firetail builds by far the most substantial and attractive nest.

Serventy and Whittell (1951) have described the structure as retort shaped. It comprises a spherical nesting chamber connected to a long tunnel, together measuring up to 16 inches in length. The tunnel itself may be 7 inches long, by 2-3½ inches in diameter. Height and breadth of the chamber may be 6 inches. The chamber consists of two parts. In the interior is a second cup-shaped "nest," which has thin, weak walls and is almost devoid of roofing.

Both are constructed of different materials. The inner nest is made of pieces of grass, whilst the exterior is composed of strips of the liana-like Twining Fringe Lily (*Thysanotus patersonii*). Morgan (1919), in South Australia, found a nest of the Beautiful Firetail built of the twining *Clematis*. The four nests I was able to examine in Tasmania were built of grasses only.

The tunnel, likewise constructed of twining stems, is continuous with the under side of the chamber and lies along a branch with the entrance over toward one side of the distal end. The chamber and tunnel walls are from 1-1½ inches thick, the sides and roofing of the chamber being more durable than the base. This is in direct contrast with the inner nest. Even if a considerable pull is exerted on the outer chamber it is extremely difficult to destroy. Its great strength is probably due to the liana-like quality of the twining stems, which wind about each other. Since the nest is built in the weak terminal branches of a eucalypt, where the foliage frequently sways violently, such a tough construction is highly adaptive.

As far as I have observed the Red-eared Firetail uses only green plant material in the building of its nest, although this quickly dries and turns yellow in the sunlight. The protected inner parts, however, remain green for a good many weeks.

Of four nests investigated in detail, I found that the outer construction consisted of between 420 and 500 strips of twining *Thysanotus*. One piece was 35 inches in length—almost eight times as long as the bird which carried it—and this same piece also trailed 106 tendrils each varying from 2 to 14 inches in length!

The ability of the Red-eared Firetail to transport such material is outstanding. However, not all the pieces were of such lengthy dimensions.

The average length for the pieces which constituted the outer parts of the nest was between 16 and 20 inches. The pieces became progressively smaller toward the interior of the nest, and at the innermost limit the average length had become from 6 to 8 inches. In the Diamond Firetail I also observed this preference for very long pieces of grass for nest construction. Since the construction takes place from the inside and is brought outwards, an urge to bring longer and longer pieces results in this type of order in the building material.

The tunnel is built similarly and the *Thysanotus* strips constituting the outer nest chamber are laced into the fabric of the tunnel and vice versa. In this manner the two are bound inseparably together as one. The tunnel is constructed after the nest chamber is already built, so that the longest pieces are found in it. Some of them are wound around the circumference of this tunnel, which consists of between 150 and 185 strips. It is never lined with either plant down or feathers.

The cup-shaped interior nest is made up of between 230 and 360 pieces of grass, primarily *Stipa elegantissima*. This material is considerably softer than the twining stems of the outer nest and tunnel. Like the length order in the *Thysanotus* stems, the pieces of grass become shorter toward the interior. The outer pieces measure, approximately, 8 inches whereas the innermost are only about two inches long. The entire unlined nest comprises between 800 and 1,045 pieces of plant material, and is thus almost twice as large again as the nest of any other species of Australian finch.

The lining of plant down and feathers is added later. The amount used does not appear to be of a fixed quantity, but seems to depend upon its availability. Cayley (1932) cites F. L. Whitlock who reported: "It will be noted that there is no separate lining, the five or six pure white eggs simply lie on the general fabric of the nest."

In a breeding nest of a Red-eared Firetail Warham (1954) found only six feathers, whereas one of the nests investigated in my study area contained 310 feathers and the same amount of plant down. There were almost 2,000 pieces of material in this particular nest. The feathers in its lining very probably originated from a single Western Rosella (*Platycercus icterotis*), which had died in the vicinity, and had been found by the Red-eared Firetails. The Beautiful Firetail also uses feathers for the lining of the nest. Feathers of any colour may be taken for lining but, as is usual in all Australian finches, the Red-eared Firetail has a preference for white. North (1909) recorded one nest of the Beautiful Firetail in South Australia lined with *black* feathers.

As well as breeding nests, the Red-eared Firetail probably builds roosting nests for use in the non-breeding season. Because of the unfortunate lack of time I was unable to ascertain whether these structures were made only for roosting, or if they were abandoned breeding nests, used for roosting after the end of the breeding season. All were unlined, and save for a two to three inch long extension of the entrance, almost entirely lacked a tunnel. In all other respects, the nests had been built in the same manner as the breeding nests.

Similar, but poorly constructed roosting nests are made by the Zebra Finch and other finches. Invariably, however, these birds first attempt to find an abandoned nest, belonging either to their own or another species, which may need only to be reorganised.

As has been demonstrated, the nest building of the Red-eared Firetail has reached a higher point in the evolutionary scale than has that of any other species of Australian finch.

For some time these grass-finches had been considered a sub-family (Estrildinae) of the true weavers (Ploceidae) (Delacour, 1942; Morris 1958). Because, however, of the great differences in anatomy, physiology and behaviour most recent workers are of the opinion that the grass-finches constitute a separate family, the Spemestidae or Estrildidae (Beecher, 1953; Steiner, 1955; Wolters, 1957; Immelmann, 1959; Ernst Mayr, pers. comm.).

The nest building of the grass-finches, especially that of the Red-eared Firetail, strongly supports this opinion. The true weavers (Ploceidae) begin nest construction by weaving a few pieces of grass around a twig. Then a ring is formed representing the side walls-to-be, after which the roof is added. Not until the end are the base and egg chamber properly built (Laek, 1935; Skead, 1956, 1959; Collias and Collias, 1959). This is in direct contrast to the method employed by the grass-finches. These build an open cup-shaped structure on the fork of a branch, but never weave it. The side walls and roof follow in that order.

(vi) INCUBATION

Both sexes of the Red-eared Firetail assist in the incubation of the eggs, as is characteristic of all finches.

Each period-on varies between $1\frac{1}{2}$ and 2 hours, the average being one hour 40 minutes in 14 instances observed in the study area. At the end of this time the change-over of mates takes place, always preceded by the Intimate Nest Call described previously. Both birds incubate for the same total period of time each day, in interrupted sessions. At night the two retire into the nest together.

Never does the male Red-eared Firetail come to the nest to feed his mate by regurgitation, as has been described by Warham (1954). The feeding of an incubating bird by its mate is recognised as occurring only in the true finches (Fringillidae), and is completely unknown in the grass-finches (Estrildidae).

At the relief of the incubating female the male Red-eared Firetail will sometimes bring a feather in his bill, held by the middle of the rachis. This behaviour depends upon the availability of feathers in the neighbourhood, as does the amount of lining incorporated in the nest. Feathers, when available, are brought in this manner throughout the incubation period, and Warham (1954) states that even when the young have reached eight days of age the behaviour was continued.

The Red-eared Firetail incubates more tightly than any other species of finch. While the latter leave the nest with extraordinary lightning-like rapidity on any disturbance, I found it extremely difficult to induce an incubating Red-eared Firetail to interrupt its incubation. Even by violently shaking the bough, which held the nest, or throwing stones against the branches, I was unable to force the bird out. It was not until my hand was actually at the entrance to the tunnel that the bird emerged.

This persistence in covering the eggs, even during unusual external circumstances, is probably the result of the type of nest built by the species. Within the walls of the strongly constructed nesting chamber, open only at the tip of a substantial and narrow tunnel, an incubating bird is well protected from intruders. The bird arriving to relieve its mate on the nest never alighted before the nest entrance. It always landed in the opposite side of the tree, and from there hopped through the branches toward the nest.

Unlike other species of Australian finches this bird employs a method of incubation change-over which I shall term Direct Relief. The relieving mate actually enters the nest and remains inside with its partner for a few seconds before the relieved bird emerges. The incubating Zebra Finch, and other species of finch, will leave the eggs and fly from the nest as soon as the mate alights somewhere nearby in the nesting tree. This type of change-over I term Indirect Relief.

Direct Relief in the Red-eared Firetail is probably an adaptation to the nest construction. Being completely hidden from view, the bird covering the eggs is able to assure its mate through the

mechanism of the Intimate Nest Call that the internal nest conditions are normal.

At close of day the bird which happens to be out and foraging in the neighbourhood does not return to the nest until approximately 20 minutes after sunset. Most other Australian finches are settled for the night before sunset.

During the hatching period both birds of the pair sometimes remain together for up to 30 minutes at a time in the nest during daylight hours. It appears that this behaviour is nothing more than a prolongation of the Direct Relief change-over.

The eggshells of the newly hatched young are carried out by the parents at the change-over of incubation. They are never deposited in the immediate vicinity of the nesting site, but are dropped during flight, over 30 or 40 yards away. In the Beautiful Firetail the carrying out of the eggshells has been observed by H. E. Peir (Cayley, 1932).

There is no evidence of nest sanitation since the nest becomes soiled and hardened with the droppings of the nestlings. The statement of Warham (1954), that the parent birds swallow the faeces of their young, has not been proved for any species of grass-finch (Estrildidae).

BEHAVIOUR OF THE YOUNG

Due to the destruction of an active nest by a Carpet Snake I was unfortunately unable to observe the feeding and behaviour of the young both before and after leaving the nest. This particular nest was the only one which could have provided me with the data during my short visit to the area.

Warham (1954) states that the young are brooded by the parent birds until the eighth day of life. His belief, however, that only the female covers the young is certainly an error. The described "visits of the male every forty minutes" were only the change-over of mates in brooding sessions.

The period-on is necessarily shorter than that during incubation of eggs since the young must be fed at regular intervals. Therefore the $1\frac{1}{2}$ -2 hours period-on during incubation is reduced to only 40 minutes after the chicks have hatched.

In December I watched three young Red-eared Firetails at approximately 10 to 12 weeks of age, undergoing heavy moult into adult plumage. As the juvenal plumage of the Red-eared Firetail has not been described I have included the following notes.

The eye-ring of the juvenal bird has an inconspicuous tinge of blue. This signifies that the bright colour of an adult is attained only after the completion of the moult. Even in fully adult Red-eared Firetails the eye-ring tone is variable. In the breeding season the colour is intensified, becoming duller in the non-breeding season.

The bill of the young bird—as usual in most Australian finches—is black. As the post-juvenal moult continues, however, the typical red sheen becomes evident.

There is no red ear-patch and no black stripe through the eye.

The upper parts are grey-brown, considerably duller than those of the adult bird. The lower breast and abdomen show none of the white spotting seen in the mature individual, but are marked with equally spaced alternating light brown and dark brown undulating stripes. Thus the young Red-eared Firetail resembles the Beautiful Firetail of the east and it is only after the moult that the plumage differences between the two species become obvious.

The three young birds under my observation spent all their time within the parental territory. They were always together and called to each other with long Identity Call series as used by mated pairs in the breeding season. True Nest Site Calls were also sometimes uttered by these juvenals, but were never associated with grass carrying as in mature birds.

As is typical of many young birds, especially grass finches, the juvenile Red-eared Firetail shows indications of the awakening of sexual behaviour during the post-juvenile moult.

TERRITORIAL BEHAVIOUR

I have found most Australian finches tend to breed in colonies. This means that several pairs form a breeding community in the same bush or group of bushes. In such a case, the territorial defence tendency is weak. The Red-eared Firetail, however, always bred as solitary pairs. None of the nests I examined were within 100 yards of each other. Nevertheless there is no territory in the sense that is applied to many other species of distinctly territorial birds, and usually only the immediate vicinity of the nest is defended.

The entire territory comprises a circular area of from 100 to more than 200 yards diameter around the nest site.

Territorial defence behaviour is at its highest intensity during the nest-building and courtship period. During the moulting-period it is completely absent. As soon as a strange male—looking for a nesting site—approaches the area of an occupied nest, the breeding bird will fly towards and pursue it until more than 100 yards are between the nest and the intruder. In the defence of the nest itself the female is as active as the male.

No definite statement can yet be made regarding defence of the outer limits of the territory.

On several instances I observed an established male Red-eared Firetail finch chasing another male back and forth within the territory, to which the strange male had meandered. The intruder, which ultimately left, had been in search of a nesting site and was carrying a piece of grass in his bill. These males, however, could have been the same two observed feeding together some time later, beneath the nesting site of the bird in possession of the territory.

Obviously the territorial defence reaction is not always at high intensity, and reaches a maximum only at certain stages of the cycle. This is similar to the behaviour of the Beautiful Firetail and of the Zebra Finch, as well as the other Australian grass finches. It is quite possible that the response elicited was more powerful under the added stimulus of the piece of grass in the intruder's bill.

A nesting site is defended even though not definitely accepted by a pair. A male in search of a site, carrying a piece of grass in its bill, will vigorously chase off another male although there is no actual territory to defend.

The Red-eared Firetail thus possesses a large territory, but defence of the area as a whole appears to be relatively weak. The strongest defence is applied to the immediate vicinity of the nest. In several other species of Australian finch this trend has gone another step further. Since they build in close proximity to one another, defence is confined to the nest itself only.

RELATIONS WITH OTHER BIRDS

Singing Honeyeaters (*Meliphaga virescens*) pursued the young Red-eared Firetails, but never closed in with positive attack. This species of honeyeater caused much damage with the eggs and young in a breeding colony of Zebra Finches which were under my observation in York, W.A.

One male Red-eared Firetail was observed chasing a male Splendid Blue Wren (*Malurus splendens*).

EVOLUTIONARY STATUS

The Red-eared Firetail is considered to be one of the most primitive of the Australian grass-finches and many of its activities are of low order in the evolutionary scale. On the other hand it is efficiently adapted to its environment, particularly in regard to nest construction and associated behaviour. The complex construction of the nest is unique amongst nests of all other Australian finches.

The Beautiful Firetail of south-eastern Australia seems to be even closer to the common ancestor of the Australian grass-finches. Its behaviour and biology show still more primitive characters and it lacks the special adaptations to life in dense undergrowth. From a species similar to the Beautiful Firetail the other members of the genera *Zonaeginthus*, *Buthilda* and *Neochmia* may have developed, the Red-eared Firetail being a side-line with special adaptations.

SUMMARY

In this paper the behaviour of a natural population of Red-eared Firetails (*Zonaeginthus oculatus*) has been described. Comparative observations on the behaviour of some other species of Australian finches are included.

The Red-eared Firetail lives in seclusion in heavy forest, usually only with its mate and always within the territory. The species never forms flocks as does *Zonaeginthus bellus*, its south-eastern Australian counterpart.

Flight is usually low, relatively level and slow, and is never associated with calls. The bird hops in finch-like manner, but with one exception the wings and tail remain motionless. A slight tail twisting following a turn in a new direction is the only noticeable divergence from the normal position.

Typically a seed eater, this bird may prey on small insects in the breeding season. It feeds alone, seldom directly on the ground.

Seed heads of grass are held with either foot whilst the seeds are removed by the bird perched on a fallen twig. No call is uttered during feeding, since there is no associated flocking.

Three types of calls given by the Red-eared Firetail are described, all of which are uttered in specific conditions: the Identity Call, the Intimate Nest Call, and the Nest Site Call. The Intimate Nest Call, given at the change-over of incubation, is unique amongst Australian finches, and has probably evolved from the manner in which the nest is constructed.

The male selects the nest site, after which it is shown to the female for acceptance or rejection. Calling by the male bird is associated with grass holding and some plumage erection in display when the female is to be attracted to the site.

The Nest Site Call is given when the female arrives at the site, but there is no tail fanning as in the Zebra Finch. If the site is accepted, the female remains, but if it is unsuitable she flies off, after which the male will begin afresh in another tree.

Courtship conforms largely with that of the majority of grass finch species. It is begun by the male uttering the Nest Site Call as he carries a length of grass in his bill. With the female nearby, the male will jump back and forth between two branches, uttering the call only upon each landing. Still holding the grass, he eventually alights near the female and springs repeatedly up and down. This is associated with some plumage erection and an exaggerated stance. A receptive female invites copulation by quivering her tail, stimulating the displaying male to drop the grass and mount.

In nest-building the male carries grass from beneath the nesting tree to the nest site, where the female does the construction. Green plant material is used exclusively, and lining is added after the outerparts of the nest are completed.

The nest is built between 25 and 50 feet above the ground, which is higher than that of any other Australian finch. It is constructed in the peripheral twigs of a tree and is the most attractive and substantial of all Australian finch nests, as well as almost twice as large. It is retort-shaped, with a spherical nesting chamber connected inseparably to a long, narrow tunnel. In the interior of an outer chamber, the actual breeding nest is constructed. The two are composed of different material, of which the outermost, composed of twining stems, is the stronger. Roosting nests are also constructed.

Both birds of the pair share in incubation, in periods-on of 1-1½ hours. The mechanism of incubation relief is different to that of other species of finch, and is fully discussed. The bird is persistent in incubation even during unusual external conditions. This is probably the result of the protection afforded by the robust type of nest. Eggshells are carried some distance from the nest, but there is no evidence of nest sanitation.

Juvenal birds show indications of sexual behaviour soon after becoming independent. The hitherto unrecorded juvenal plumage is described.

A large circular territory, of 100 to more than 200 yards in

diameter, is occupied about the nest, but, on the whole, is weakly defended. Continually strong defence is applied only to the immediate nest vicinity.

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LATE QUATERNARY CHANGES IN THE VEGETATION ON ROTTNEST ISLAND.

By D. M. CHURCHILL, Botany Department, University of
Western Australia.

The present vegetation on Rottnest Island has been described by Storr, Green and Churchill (1959) as a *coastal complex* made up of fairly open microphyllous shrubs in the coastal dunes; 10-20 foot high *Acacia rostellifera* scrubs in the sheltered valleys and slopes; closed mixed shrubs of the limestone ridges; and salt marsh communities around the lakes and swamps. During white settlement, prior to administration by the Rottnest Island Board of Control, widespread destruction of the vegetation took place through clearing for agriculture, chopping down trees for building and firewood, and unchecked burning which followed firing of the scrubs for Quokka shooting. The *Acacia rostellifera* scrubs were reduced to isolated thickets, and where the scrub once stood there now occurs a low dense formation consisting of sclerophyllous monocotyledonous plants, of which *Acanthocarpus preissi* and *Stipa variabilis* are the most prominent. The present balance between the *Acanthocarpus-Stipa* formation and *Acacia* scrub is controlled by fire frequency and intensity of Quokka grazing.

From the foregoing account it is evident that considerable changes to the vegetation have taken place on Rottnest Island over the last one hundred and fifty years. These changes may be attributed both directly and indirectly to the influence of white settlement. It is the purpose of this paper to give an account of the prehistoric changes in the vegetation that have occurred since the isolation of Rottnest as an island between 4,000 and 5,000 years B.C.

FOSSIL EVIDENCE

During the reorganisation of the fossil plant collections at the Western Australian Museum, the attention of the author was drawn to a specimen which consisted of the fibrous pith of the apical meristem of a Blackboy (*Xanthorrhoea* sp.). This specimen (Fig. 1) (Museum No. G9066) came from sediments encountered 19 feet below the surface, when a well was sunk at Rottnest Island, and was given to the Museum by Mr. A. Armit. No Blackboys have been found on the island since white settlement, and as